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RESEARCH MEMORANDUM

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U. S. Army Ordnance

A WIND-TUNNEL INVESTIGATION OF THE EFFECT OF NOSE RING SPOILERS ON A LOW-SPEED SLOWLY SPINNING FIN-STABILIZED ROCKET

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A WIND-TUNNEL INVESTIGATION OF THE EFFECT OF NOSE RING SPOILERS ON A LOW-SPEED SLOWLY SPINNING FIN-STABILIZED ROCKET

By Jacob H. Lichtenstein

SUMMARY

An investigation has been made in the Langley stability tunnel with a model of a low-speed slowly spinning fin-stabilized rocket to determine the effectiveness of a nose ring spoiler in reducing the unstable Magnus moments on a sting-mounted completely spinning model, and, if possible, to find the effect of a nonspinning center section, used in a previous investigation, on the unstable Magnus moment.

The results of the investigation show that a spoiler is quite effective in reducing the unstable yawing moment and that this effectiveness is dependent upon proper location of the spoiler. Wherever the results for the completely spinning model and the one with a stationary center section are comparable, the completely spinning model shows somewhat higher yawing moments and side forces than the other model.

INTRODUCTION

The instability exhibited by fin-stabilized spinning missiles has been of considerable concern for some time. In brief, this instability develops because of a combination of the aerodynamic moments due to large angles of yaw of a spinning missile (Magnus effects) and the gyroscopic moments due to spin, and it manifests itself by the development of a precessional motion having a large amplitude. This behavior appreciably shortens the range and may cause destruction of the missile prior to completing its mission. In attempting to gain some insight into the problem, numerous investigations, both experimental and analytical, have been made. (For example, see refs. 1 to 5.)

[redacted]

The data presented in references 1 and 2 for a particular missile of this type (a low-speed slowly spinning fin-stabilized antisubmarine rocket) indicated that a nose ring spoiler was effective in reducing the unstable aerodynamic moments of the spinning missile. In both these investigations, however, it was necessary to maintain a portion of the model, about 1 foot long, stationary in order to attach the model to the support system. The present tests were made to check the effectiveness of the nose ring spoiler on a completely spinning model, and, if possible, to evaluate the effect of the nonspinning section of the model required in the previous tests on the unstable moments.

The model used in this investigation was a sting-mounted model, tested with and without the nose ring spoilers through an angle-of-attack range from -4° to 27° and for rates of spin from 50 to 600 rpm. The tests were made at a Mach number of 0.13.

SYMBOLS

The data are presented in standard coefficient form about a body-axis system through the desired center of gravity of the model. The positive direction of the forces, moments, angles, and angular velocities are shown in figure 1. The coefficients and symbols are defined as follows:

C_N normal-force coefficient, $\frac{F_N}{qS}$

C_Y side-force coefficient, $\frac{F_Y}{qS}$

C_n yawing-moment coefficient, $\frac{M_Z}{qSl}$

C_m pitching-moment coefficient, $\frac{M_Y}{qSl}$

C_l rolling-moment coefficient, $\frac{M_X}{qSl}$

F_N normal force, lb

F_Y side force, lb

M_Z yawing moment about Z-axis, ft-lb

M_Y	pitching moment about Y-axis, ft-lb
M_X	rolling moment about X-axis, ft-lb
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
ρ	mass density of air, slugs/cu ft
V	velocity, ft/sec
S	cross-sectional area, sq ft
l	length, ft
d	diameter, ft
α	angle of attack, deg

APPARATUS, MODEL, AND TESTS

The model used in the present investigation was a $\frac{1}{2}$-scale model of an antisubmarine rocket. A sketch of the model, with pertinent dimensions, is shown in figure 2. The basic body rotated in a clockwise direction as viewed from the rear; the arming propeller mounted in front, however, rotated in the opposite direction (counterclockwise). Three nose ring spoilers, which were made of $\frac{1}{16}$-inch welding rod and had outside diameters of $5\frac{3}{4}$ inches, $6\frac{3}{8}$ inches, and $6\frac{1}{2}$ inches, were tested alternately on the model. These were located as shown in figure 3 at the nose of the model. The model was constructed of a spun magnesium shell one-sixteenth inch thick. An aluminum bulkhead was located at the rear of the motor drive mechanism. It fitted the bearing there and formed the rear support for the model (fig. 4). Other aluminum rings were used at the front and at the boattail to add strength and maintain the shape of the model. The arming propeller housing was made of aluminum, and the propeller shaft and blades were steel. The tail was made of wood. The entire model was dynamically balanced in order to keep the inertial forces to a minimum.

The model was mounted on a sting-support system in the 6-foot-diameter test section of the Langley stability tunnel. The sting was supported by two lead screws which, when operated differentially, changed the angle of attack. The lead screws were contained within a pylon that extended from the floor to the ceiling of the tunnel. An exploded view of the sting mechanism is shown in figure 4. The sting, strain-gage balance, and drive-motor mechanism are shown in the relative positions in which they would actually be when assembled. The trailing wires were brought out through a hole in the sting. An exploded view of the model also is shown in figure 4.

The five-component strain-gage balance measured normal force, side force, pitching moment, yawing moment, and rolling moment about a body-axis system. The output from the gage was fed to the print-head system of the standard mechanical balance in order to obviate the need for reading meters. The motor drive mechanism was mounted on the end of the strain gage and consisted of a variable frequency motor and reduction gearing to give the desired spin rate. The motor was air cooled; the cool-air tube is shown among the bundle of wires in figure 4.

The tests were made at a dynamic pressure of 24.9 pounds per square foot, which corresponds to a Mach number of 0.13 and a Reynolds number of 3.8×10^6 based upon the model length. The angle of attack was varied from -4° to 27° in 4° increments except the last. Tests were made at spin rates of 50, 200, 400, and 600 rpm.

CORRECTIONS

Because of the small lift developed by the missile and the small area relative to the tunnel, no corrections for jet boundary or blockage were applied. Neither were corrections applied for the effects of turbulence or sting-support interference.

RESULTS AND DISCUSSION

The force and moment data for the basic model configuration and for an effective nose ring spoiler are presented in figure 5 for the various spin rates. A comparison of the yawing moment for the two configurations shows the rather dramatic reduction of the unstable Magnus moment achieved by installation of the nose ring spoiler. The side force also shows an appreciable decrease in magnitude due to the spoiler. The reasons why the nose ring should produce this effect are not, at present, fully understood.

The effect of the nose-ring spoiler on the normal force, pitching moment, and rolling moment is rather inconsequential for the principal problem being considered. These results, in general, agree with those presented in reference 1.

In order to show the effect of location of the spoiler, some tests were made with nose ring spoilers of smaller and larger diameters than the original. A $5\frac{3}{4}$-inch-diameter ring was located close to the flat of the nose as shown in figure 3. A $6\frac{1}{2}$-inch-diameter ring was located back on the straight portion of the body 2.775 inches rearward of the flat of the nose (fig. 3). The data for these two nose rings together with the results for the original nose and for the $6\frac{3}{8}$-inch-diameter nose rings (ref. 1) are presented in figure 6 for comparative purposes, and show that locating the spoiler back on the straight part of the body is least effective in achieving its desired purpose. Possibly, a large increase in size would make this location more effective. The small ring which was closer to the flat of the nose similarly was less effective than the original nose ring, but somewhat better than the largest ring. It appears, therefore, that location of the nose ring can greatly influence its effectiveness. The data indicate that the optimum location would be somewhere between the location for the $5\frac{3}{4}$-inch ring and the straight portion of the body. This is the location where the velocity is likely to be highest and the boundary layer thinnest.

The variation of yawing moment, rolling moment, and side force with spin rate for several representative angles of attack is presented in figure 7. These data show that these parameters varied nearly linearly with spin rate throughout the range tested.

Comparison of the completely spinning model (present tests) and the model with a stationary 1-foot center section (ref. 1) is complicated by the fact that the spin rate for the model in reference 1 was not uniform through the angle-of-attack range but varied as the ability of the tail fins to drive the model changed. (See table I.) However, a comparison of the two models (fig. 8) indicates that the completely spinning model generates somewhat larger Magnus effects than the model with the stationary center section, as would be expected.

CONCLUDING REMARKS

The results of a wind-tunnel investigation of a low-speed slowly spinning rocket supported on a sting in such a way that the complete model could be spun indicated that a nose ring spoiler was very effective in reducing the destabilizing Magnus effects obtained with the spinning model. These results agree with the results previously obtained for a similar model with a stationary center section. It was also found that the location of the spoiler had an important bearing on its effectiveness, and that the best location seems to be within the outer segment of the nose radius. Comparison of the Magnus effects for the completely spinning model with those for the model with a stationary center section showed that the completely spinning model generated somewhat larger Magnus effects but that the general trends of the data were in good agreement for the two models.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 26, 1956.

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Approved: Thomas A. Harris
Thomas A. Harris
Chief of Stability Research Division

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2. Bird, John D., and Lichtenstein, Jacob H.: Wind-Tunnel Experiments Concerning the Dynamic Behavior of a Low-Speed Slowly Spinning Fin-Stabilized Rocket. NACA RM L54D22, 1954.

3. Miller, A., and Fredette, R. O.: The Motion of a Low Speed, Slowly Spinning Fin Stabilized Rocket, Fired in the Presence of a Crosswind. NAVORD Rep. 3149, Bur. Ordnance, Sept. 22, 1952.

4. Brown, D. R., Jr.: Theoretical Investigations of the Flight Characteristics of the 12.75" Rocket Mk I Mod 0. NAVORD Rep. 5132 (NPG Rep. 1415), U. S. Naval Proving Ground (Dahlgren, Va.), Dec. 14, 1955.

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TABLE I

ROTATIONAL SPEEDS OF THE MODEL WITH STATIONARY

CENTER SECTION FROM REFERENCE 1

Original model configuration		Original model configuration plus $6\frac{3}{8}$-inch-diameter nose ring spoiler	
α, deg	Spin rate, rpm	α, deg	Spin rate, rpm
0	810	0	795
4	1,030	4	885
8	1,270	8	1,110
12	1,240	12	1,030
16	810	16	755
20	585	20	585
24	460	24	452
28	460	28	365

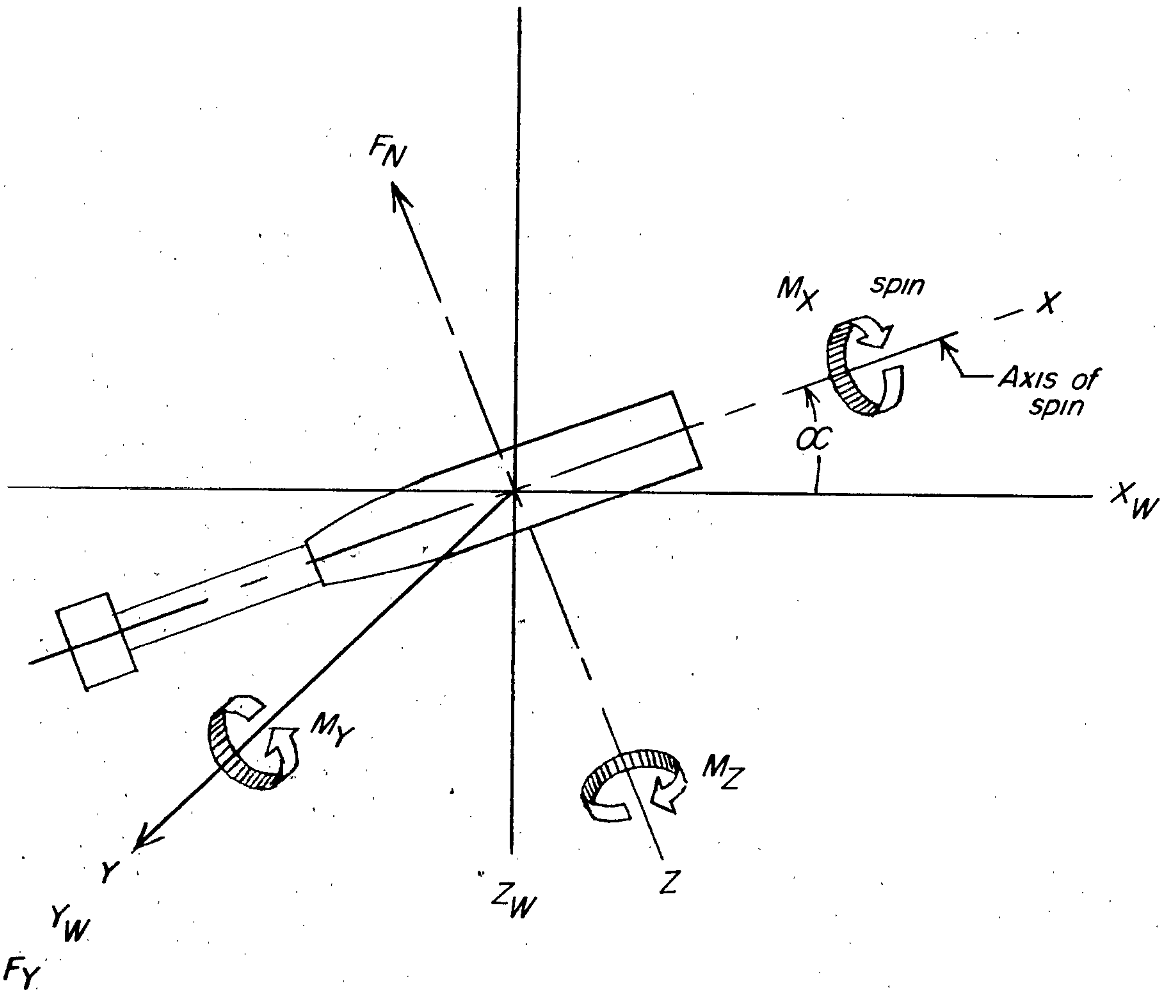

Figure 1.- System of axes used. Arrows indicate positive direction of forces, moments, angles, and angular velocity.

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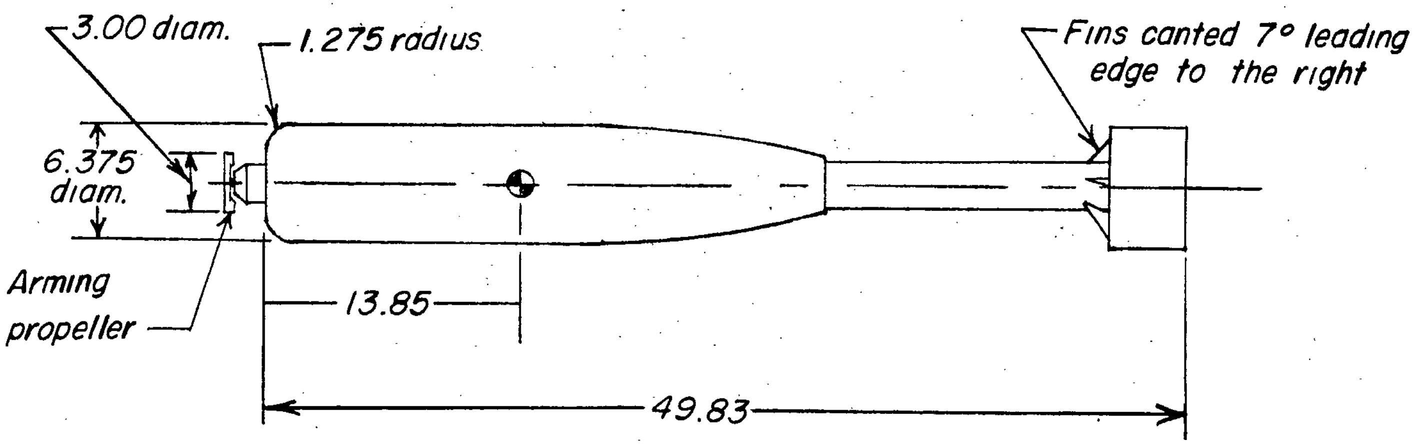

Figure 2.- Sketch of the model used in the investigation. Dimensions are in inches.

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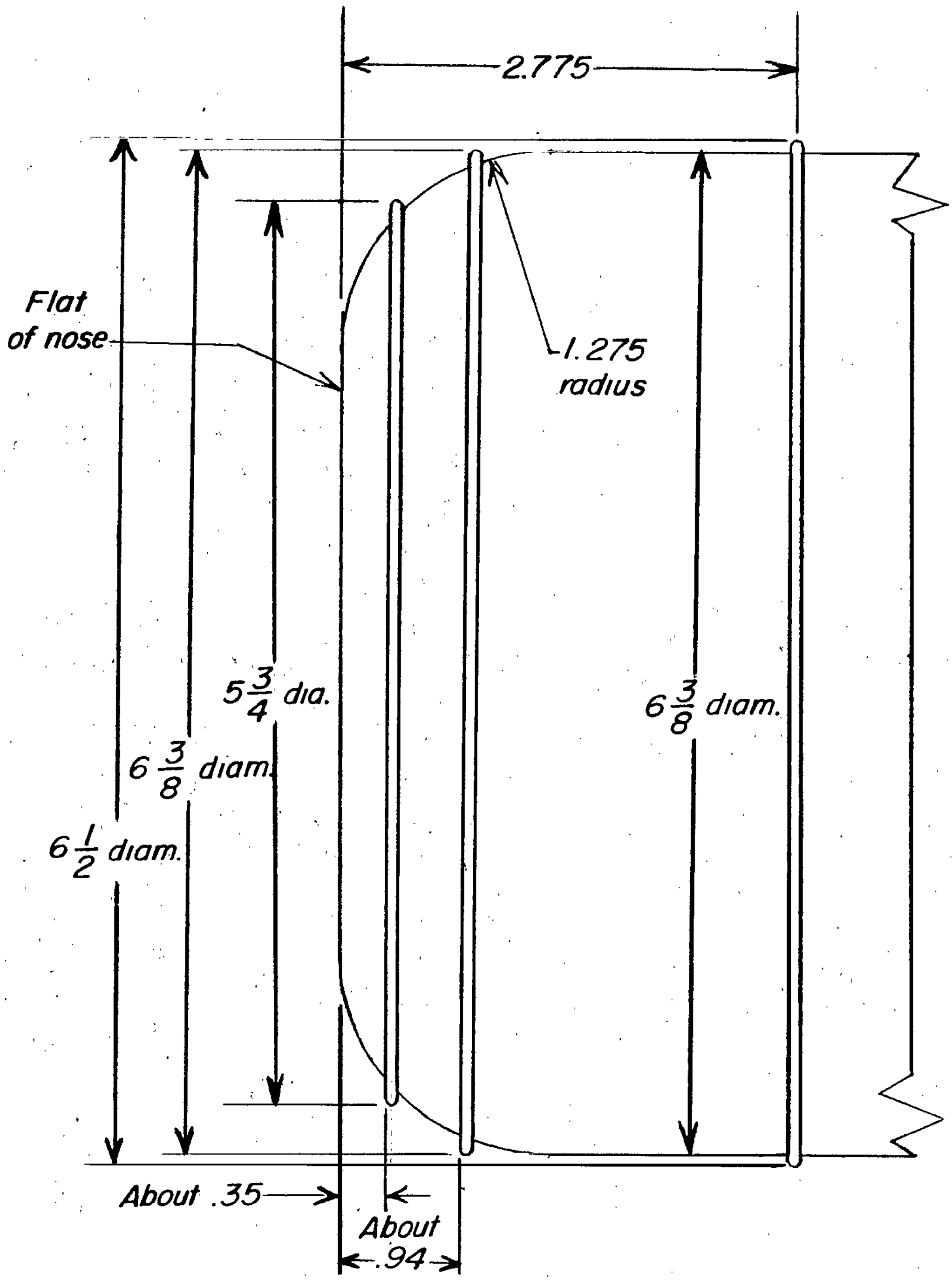

Figure 3.- Sketch showing location of nose ring spoilers for the respective tests. Dimensions are in inches.

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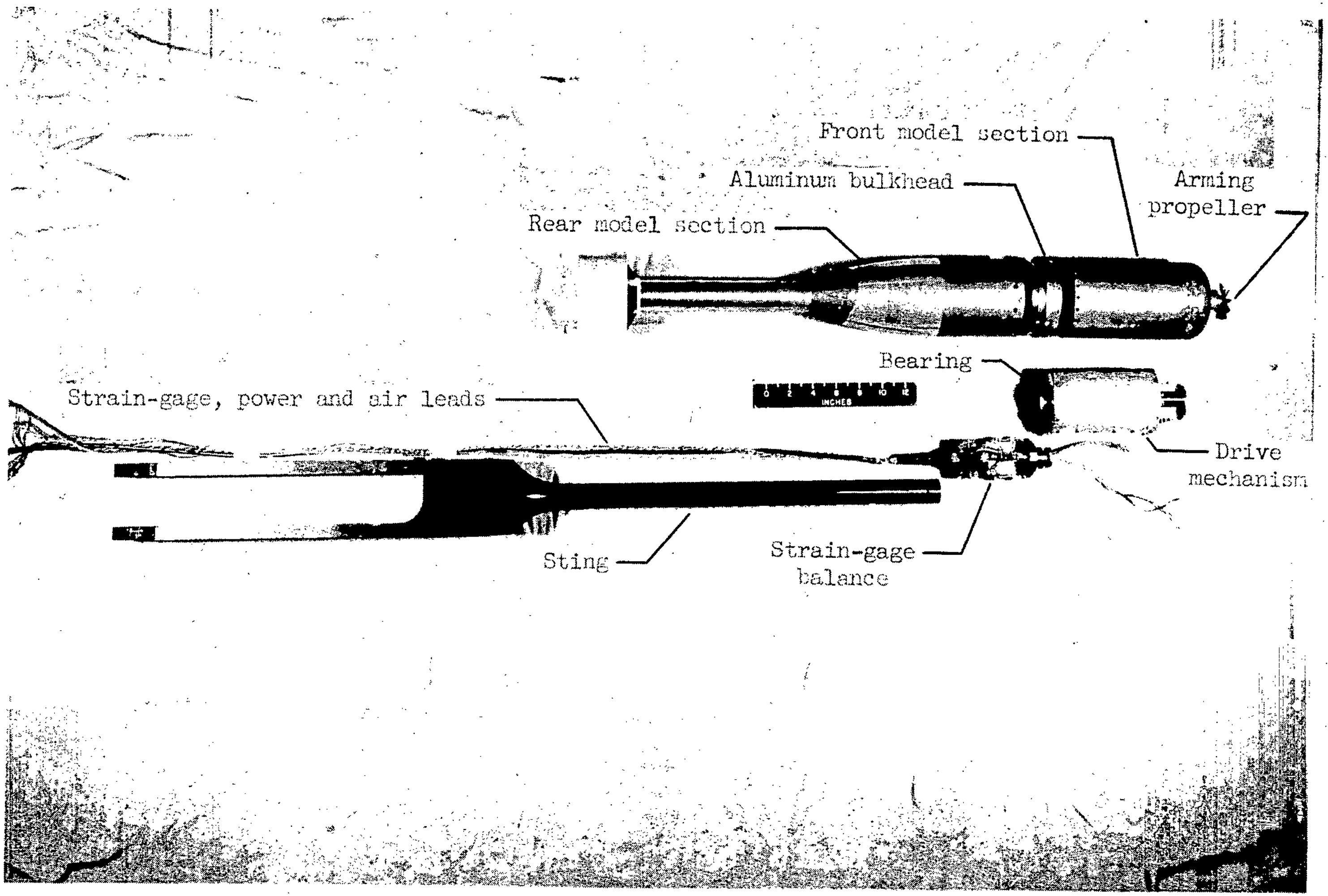

Figure 4.- Photograph showing exploded views of the mounting and drive mechanism and of the model. L-93130.1

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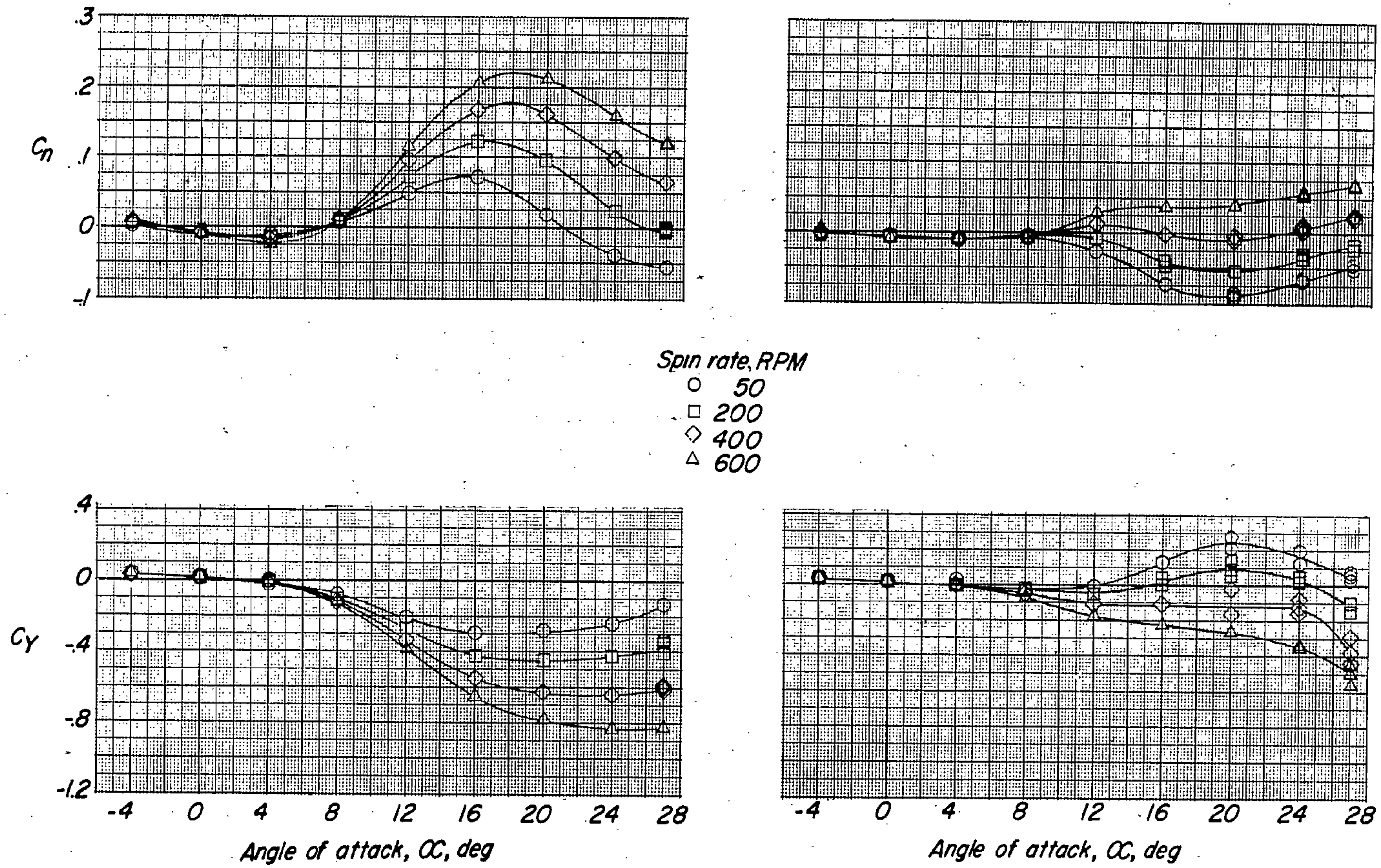

(a) Basic model configuration.

(b) Basic model with $6\frac{3}{8}$-inch diameter nose ring spoiler.

Figure 5.- Variation of the measured forces and moments with angle of attack for various spin rates.

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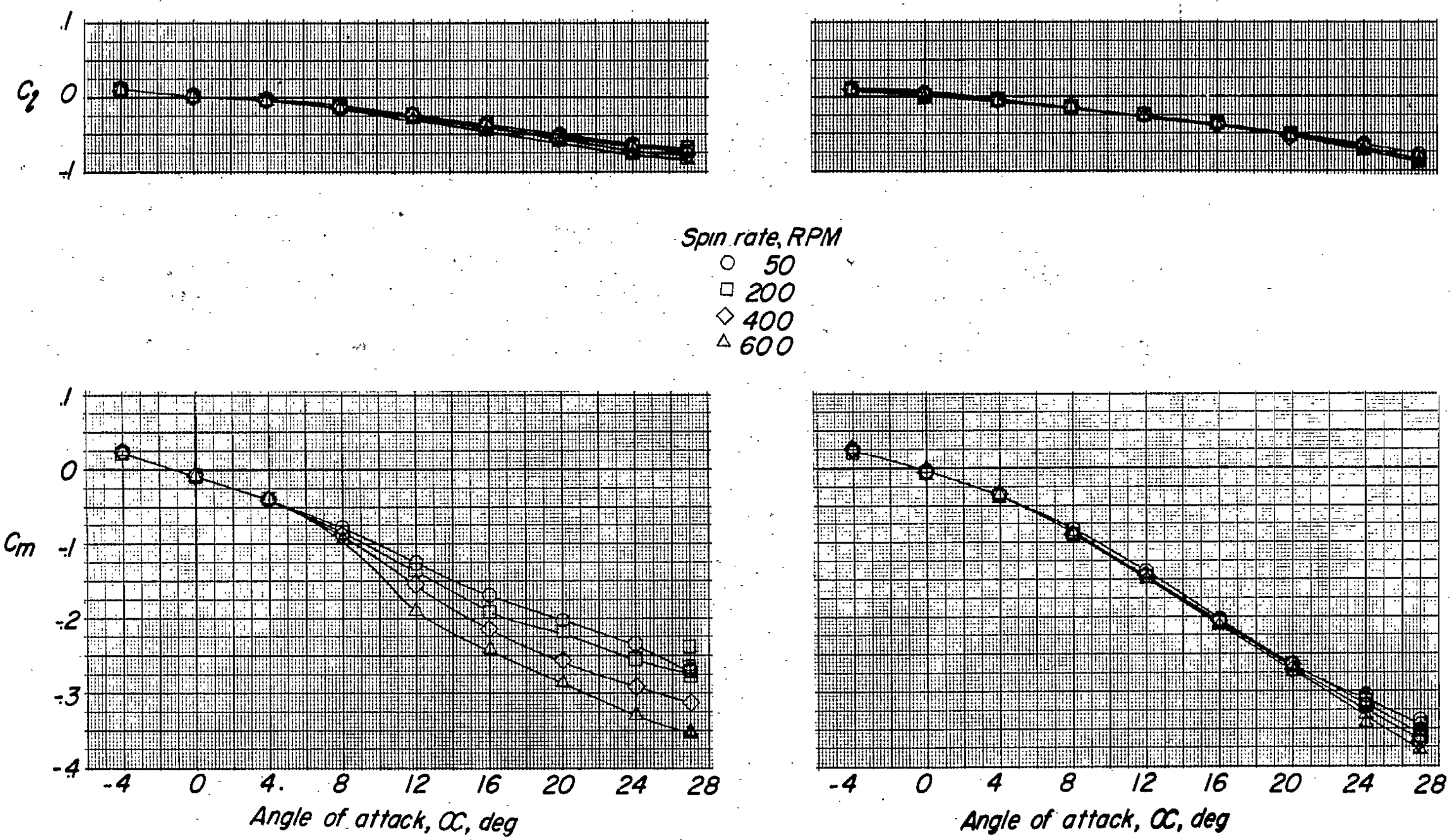
[redacted]



(c) Basic model configuration.

(d) Basic model with $6\frac{3}{8}$-inch diameter nose ring spoiler.

Figure 5.- Continued.

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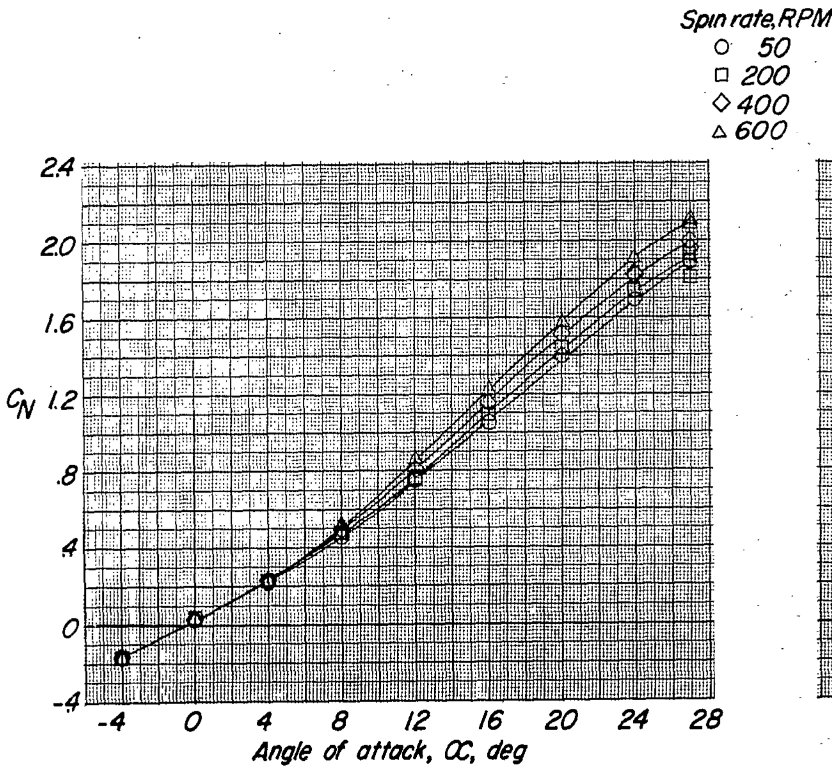
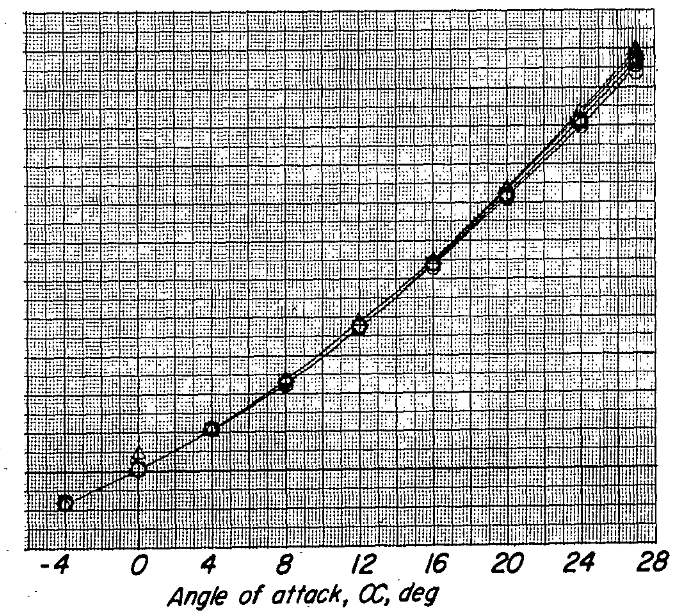


(e) Basic model configuration.



(f) Basic model with $6\frac{3}{8}$-inch diameter nose ring spoiler.

Figure 5.- Concluded.

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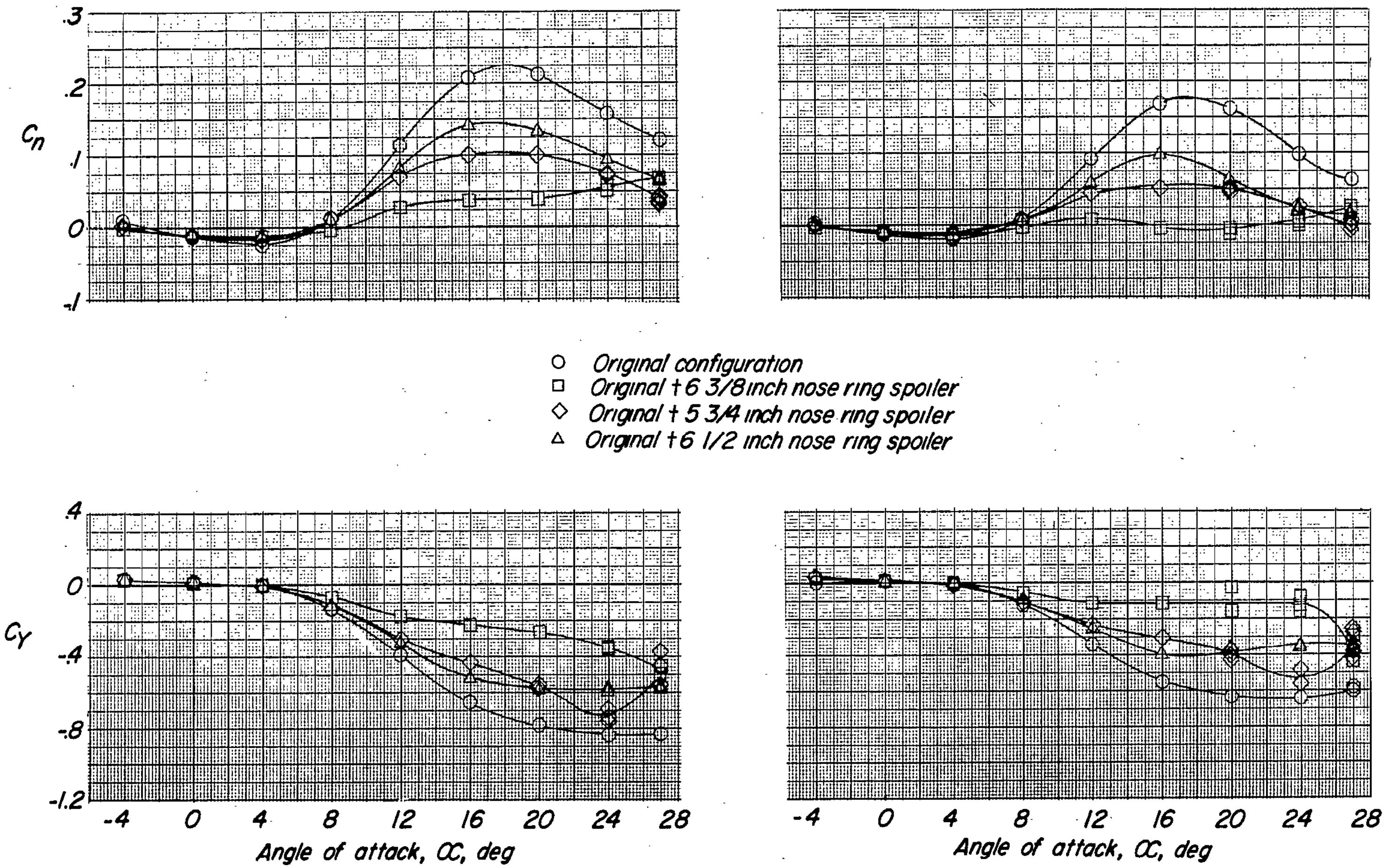

(a) Spin rate, 600 rpm.

(b) Spin rate, 400 rpm.

Figure 6.- Effect of location of nose ring spoiler for two spin rates.

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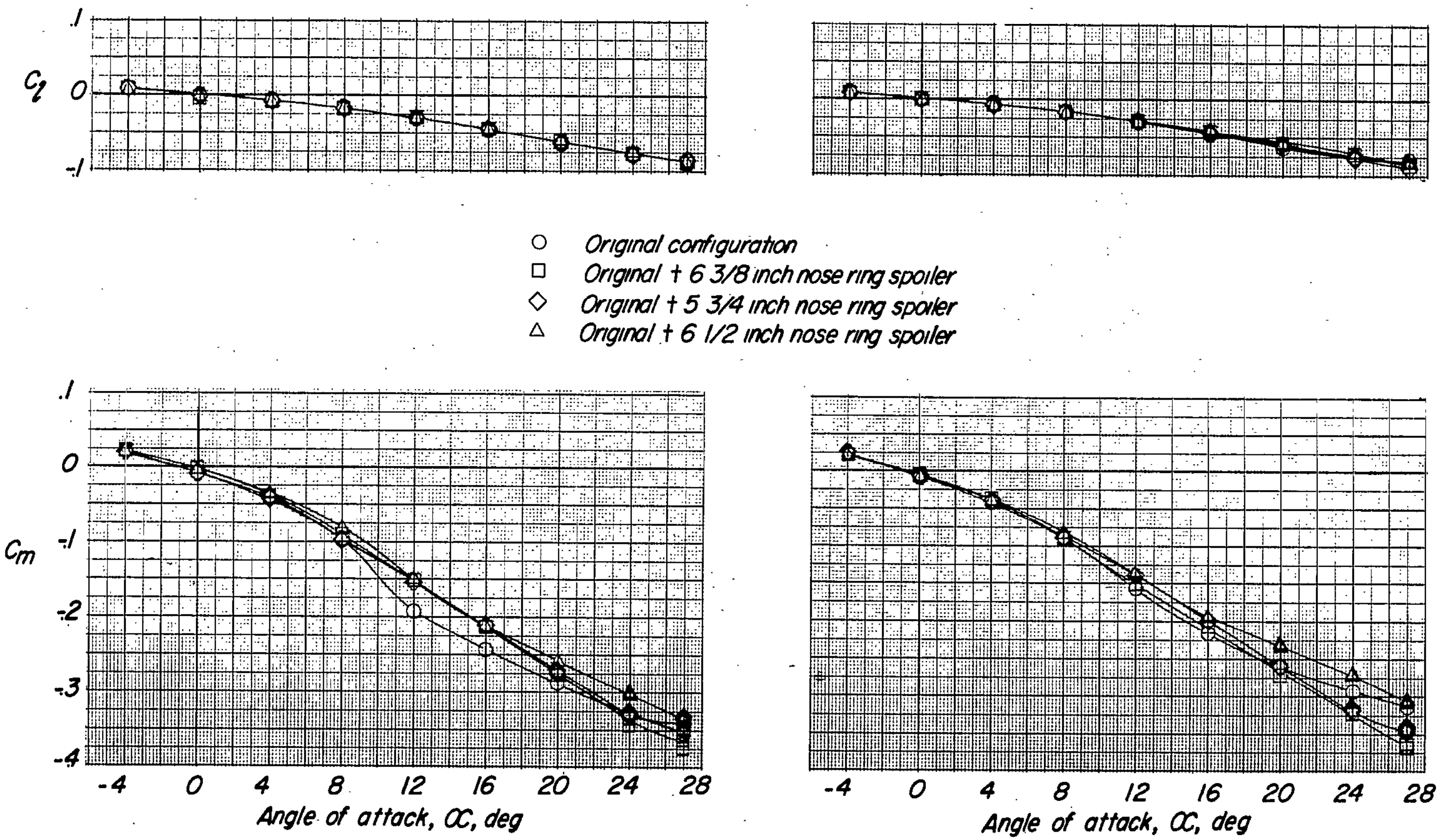

(c) Spin rate, 600 rpm.

(d) Spin rate, 400 rpm.

Figure 6.- Continued.

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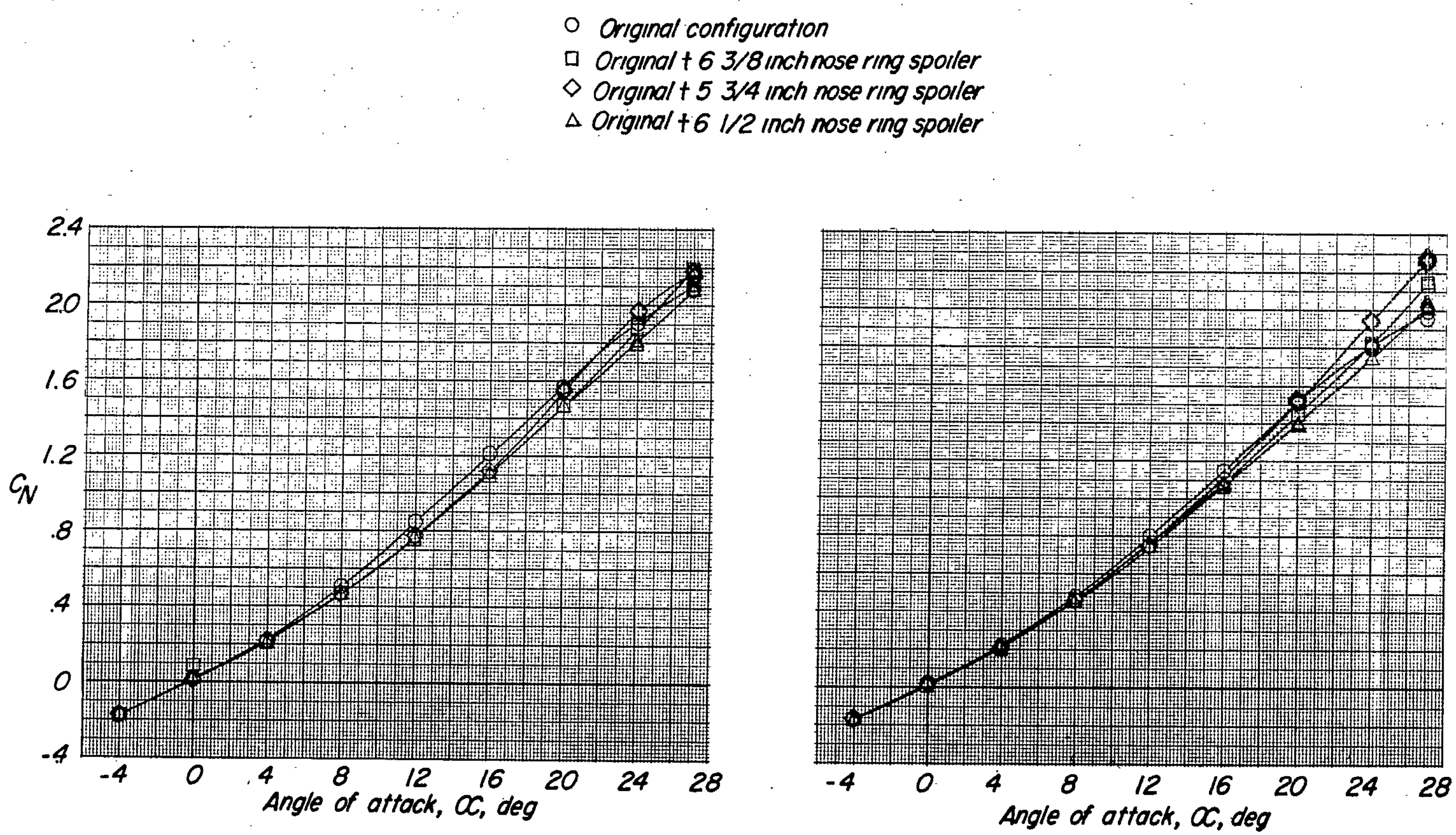
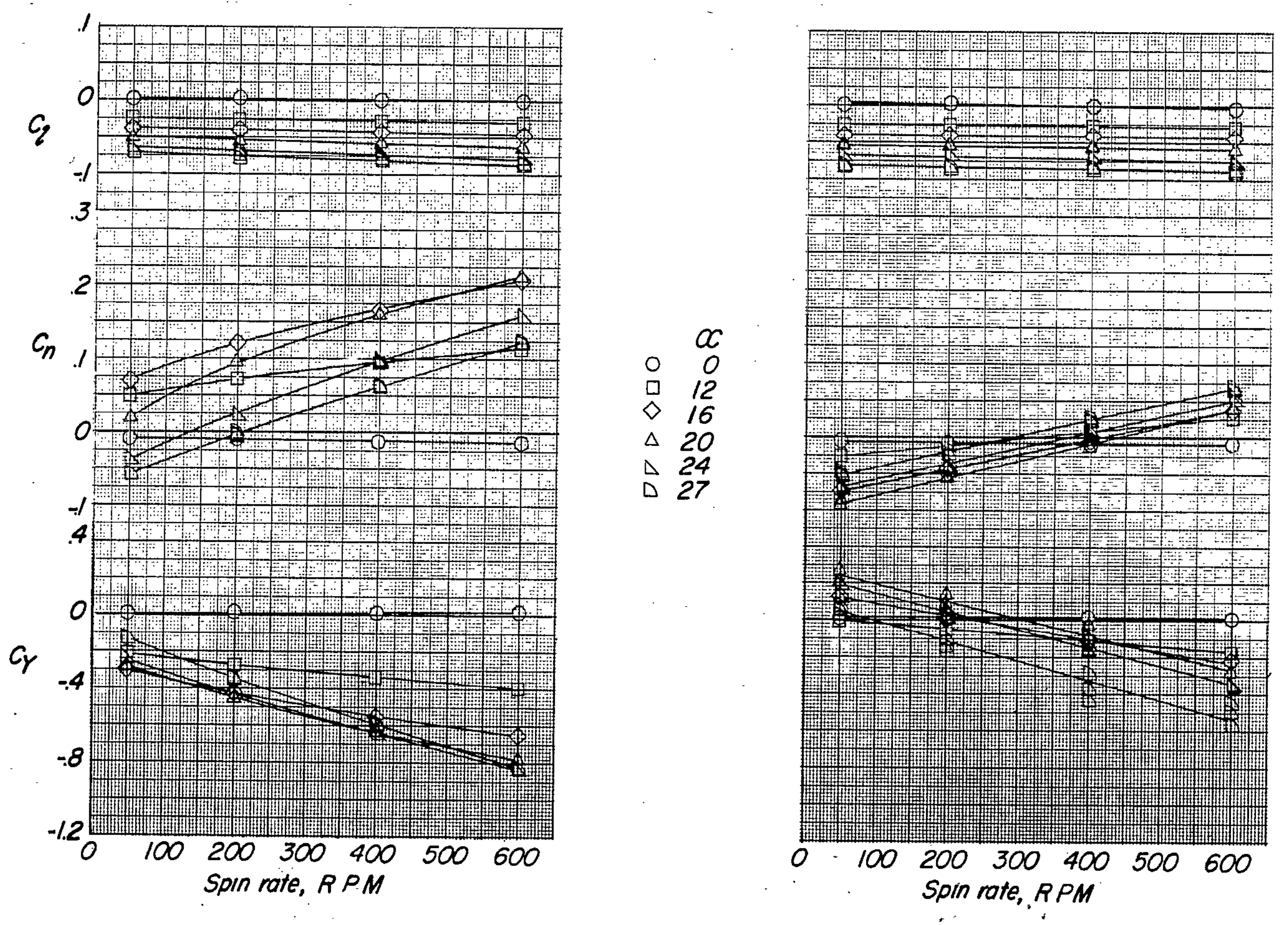


(e) Spin rate, 600 rpm.

(f) Spin rate, 400 rpm.

Figure 6.- Concluded.

[redacted]



(a) Basic model configuration.

(b) Basic model with $6\frac{3}{8}$-inch diameter nose ring spoiler.

Figure 7.- Effect of spin rate on the yawing moment, rolling moment, and side force for some representative angles of attack.

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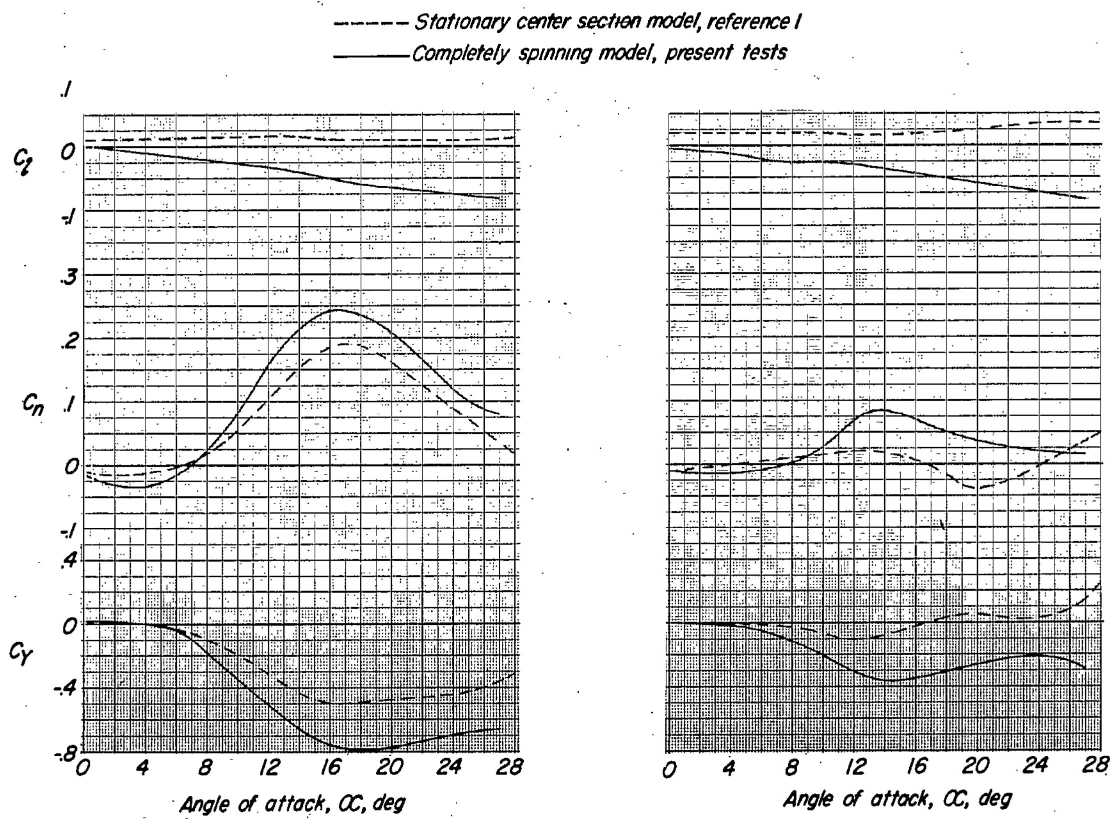
[redacted]



(a) Basic model configuration.

(b) Basic model with $6\frac{3}{8}$-inch diameter nose ring spoiler.

Figure 8.- Effect of a stationary center section of the model on the yawing moment, rolling moment, and side force for both the basic model configuration and the basic model with the $6\frac{3}{8}$-inch diameter nose ring spoiler. Data from the present tests have been extrapolated to the spin rates for the data from reference 1. (Table I.)

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ABSTRACT

An investigation was made in the Langley stability tunnel with a model of a low-speed slowly spinning fin-stabilized rocket to determine the effectiveness of a nose ring spoiler in reducing the unstable Magnus moments on a sting-mounted completely spinning model, and to find the effect of a nonspinning center section on the unstable Magnus moment. The results indicated that a spoiler was effective in reducing the unstable yawing moment and that this effectiveness was dependent upon proper location of the spoiler. A comparison of results showed that the completely spinning model had somewhat higher yawing moment and side forces than the model with a nonspinning center section.

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